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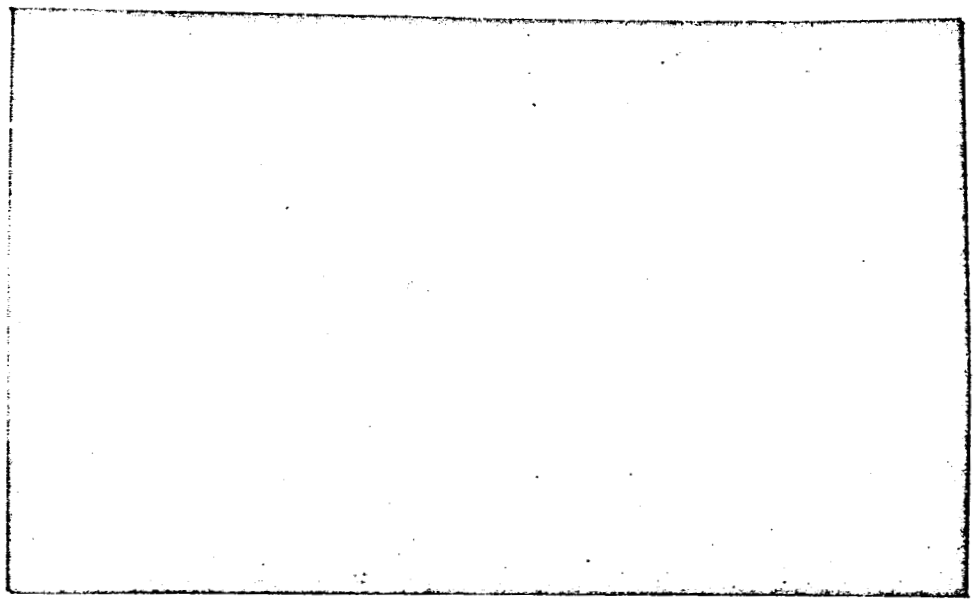

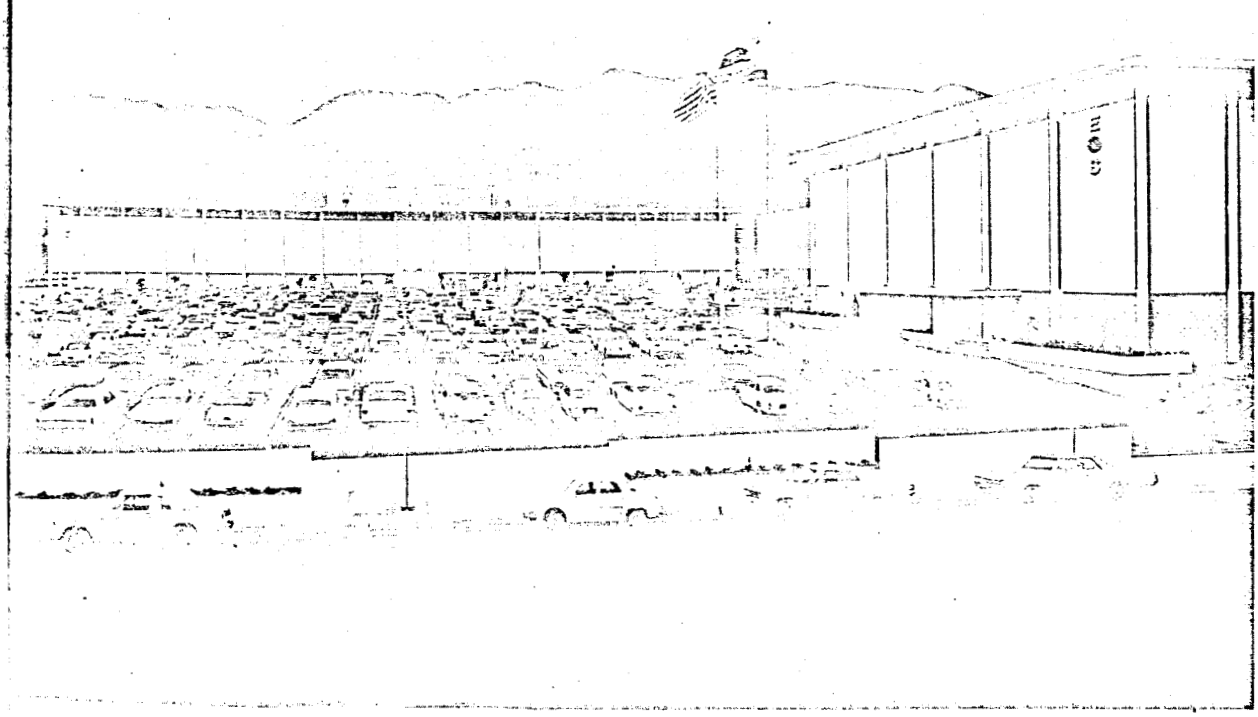

HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS

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ELECTRO-OPTICAL SYSTEMS, INC.
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CONTENTS

SECTION 1

INTRODUCTION

This report reviews the progress made on the development of a hydrogen-oxygen (H_2-O_2) regenerative fuel cell (secondary battery) under NASA Contract NAS3-2781 during the period 1 May 1967 through 1 June 1967. During this period, primary emphasis was placed on the testing of single cells with matrix structures of potassium titanate and teflon. Reference cells were assembled and tested. A six-cell unit was tested. Fabrication has begun on the 28-volt 500-watt Flight Prototype Fuel Cell assembly.

SECTION 2

TECHNICAL DISCUSSION

2.1 SINGLE CELL TESTS

Eight single cell tests were conducted during this period to evaluate matrix and electrode configurations. Test results and construction variables of these cells are summarized in Table I.

2.1.1 SINGLE CELL MATRIX TESTING

A 35-mil KT and teflon composite membrane was fabricated using the same techniques used in cells 262 and 264 then sandwiched between two 35-mil KT-asbestos mats. This matrix contained 65 gm of 39.7 percent KOH and was installed with a 60-mil spacer in cell 266. The cell contained the usual ECS-American Cyanamid electrodes. The cell has run a total of 745 cycles and the test has been discontinued. As can be seen in Fig. 1, the performance was good, above 0.7 volts on discharge, for over 600 cycles and the degradation was slow. After cycle 660 the degradation in performance was more obvious. Testing was discontinued after 745 cycles. Upon disassembly it was observed that part of the KT-teflon composite membrane had lost its latex property and appeared to have become hard, densely packed particles forming a structure like a porous brick. A KOH analysis showed a final concentration of 35 percent KOH. The degradation in performance may have been caused by the asbestos present in the mats. The electrolyte consumption was too small to affect performance. Dissolved asbestos in the catalyst reaction sites might be a factor. This cell, however, did not contain an optimum electrolyte matrix spacing arrangement and the performance may have been affected by a gradual displacement of electrolyte.

TABLE I

SUMMARY OF SINGLE CELL TESTS

Cell No.	Electrodes	Matrix	Electrolyte	Spacer (inch)	Comments
265	H_2 EOS O_2 EOS Both new and treated for one hour in 40% KOH	50/50 KT and teflon pasted membrane sandwiched between 2-90/10 KT and AB mats	40.0g of 39.7% KOH	0.060	Reverse current cycling H_2 gas concentration cell. Cell has run #1228 cycles. Test still in progress. Test temperature 80°C.
266	H_2 EOS O_2 Cyanamid Both used in run #264	80/20 KT and teflon composite membrane sandwiched between 2-90/10 KT and AB mats	65g of 40% KOH	0.060	Test discontinued after 746 cycles performance good until cycle 660 where the degradation became extreme Test temperature 80°C Final KOH 35%
269	H_2 EOS O_2 Cyanamid Both used in run #254	A 50% KT/50% teflon membrane sandwiched between two 80% KT/ 20% teflon rolled composites	56.1g of 40% KOH	0.060	Cell has run 396 cycles performance excellent. Test still in progress.
271	H_2 EOS O_2 Cyanamid New electrodes	50/50 KT and teflon pasted membrane sandwiched 2-90/10 KT and AB mats	40g of 40.3% KOH	0.060	Reference cell. After total two cycles fast self discharge.

TABLE I

SUMMARY OF SINGLE CELL TESTS (contd)

Cell No.	Electrodes	Matrix	Electrolyte	Spacer (inch)	Comments
272	H_2 EOS O_2 Cyanamid Both used in runs #263 and 270	50/50 KT and teflon pasted membrane sandwiched 2-90/10 KT and AB mats	40g of 40.3% KOH	0.060	Reference cell. After total three fast self discharge.
273	H_2 EOS O_2 Cyanamid New Electrodes	50/50 KT and teflon pasted membrane sandwiched between 2-90/10 KT and AB mats	40g of 40.3% KOH	0.060	Reference cell. After total 31 cycles fast self discharge.
274	H_2 EOS O_2 Cyanamid Both used in runs #263, 270 and 272	Pressed KT-Asbestos teflon composite 0.060" thick	47.0g of 40.3% KOH	0.050	Cell has run 292 cycles and shows excellent performance. Test still in progress.
275	H_2 EOS O_2 Cyanamid Both used in runs #272 and 273	50/50 KT and teflon pasted membrane is sandwiched between 2-90/10 KT and AB mats	45.3g of 40.3% KOH	0.060	Reference cell performance good up through cycle #43. Cycle #44 cell began to self discharge.

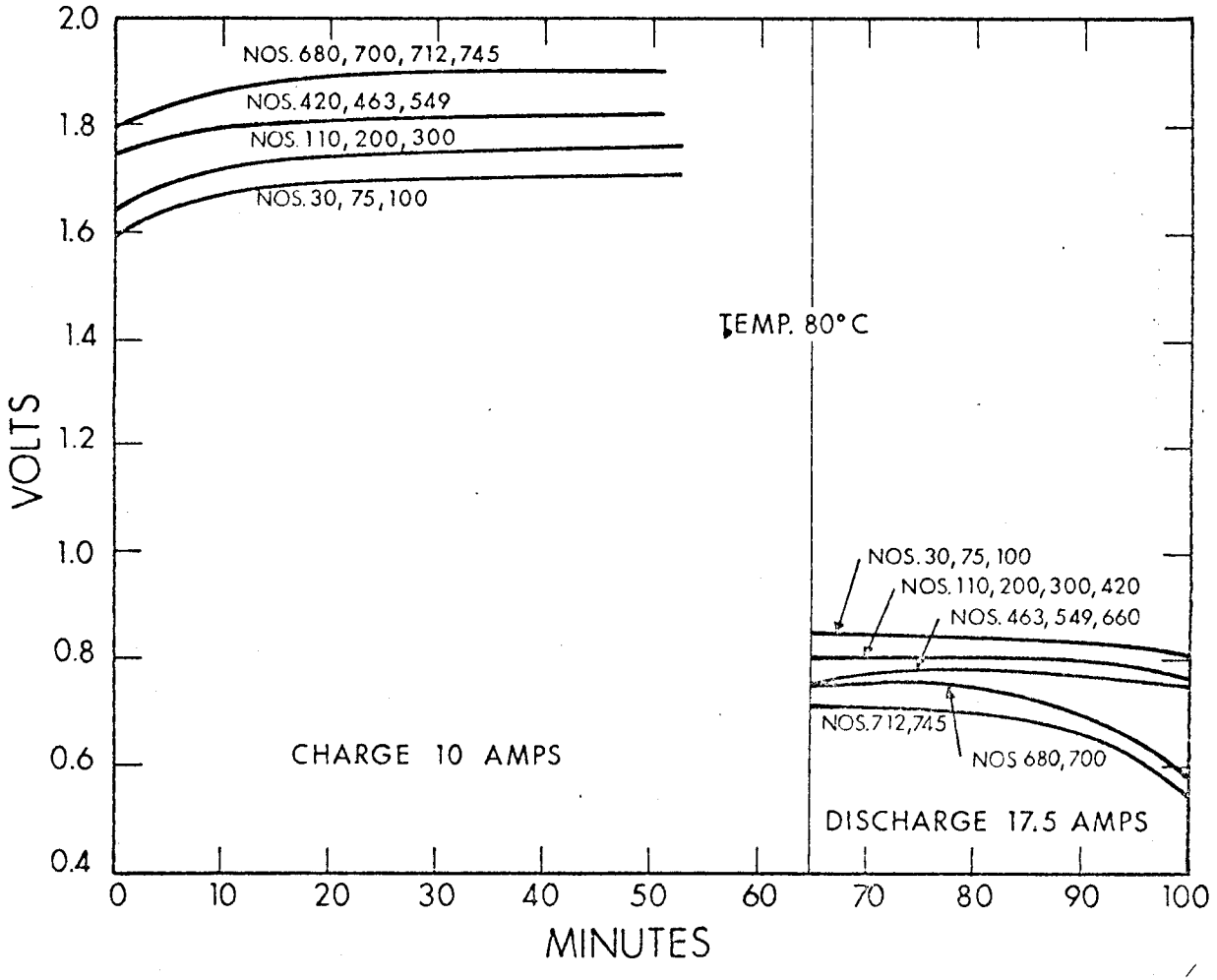

Figure 1. Cycling Performance of Cell 266

A matrix was made by forming a rolled 0.030 KT-teflon composite on each side of a membrane (50 percent KT-50 percent teflon pasted on 100 mesh screen). The matrix was assembled in cell 269 with a 0.060 spacer and 56.1 gm of 40 percent KOH. Both the EOS and Cyanamid electrodes were used in a previous cell. The cell has run 396 cycles to date and the performance is excellent, above 0.85 volts. As can be seen in Fig. 2 there has been little degradation in performance. The test is still in progress.

A pressed composite matrix was fabricated with KT, asbestos and teflon and successfully lab tested. Another matrix 0.060 inch thick was fabricated. It was assembled in cell No. 274 with 47.0 gm of 40.3 percent KOH electrolyte and a 0.050 inch spacer. The EOS Cyanamid electrodes have been used in previous cells. The cell has run a total of 292 cycles and is still cycling. Figure 3 shows that to date the performance has been most excellent, 0.9 volts and above. The degradation has been slight. The performance may have been helped by the closer spacing, 0.050 inch.

2.1.2 H_2 CONCENTRATION CELL

Cell 265 is a cycling hydrogen concentration cell. It contains two EOS H_2 electrodes and has a 50 percent KT-50 percent teflon membrane sandwiched between two 90 percent KT-10 percent asbestos mats. All the KT was treated in 100°C KOH for one hour and washed with distilled H_2O. The matrix contains 40 gm of 39.7 percent KOH. A 60-mil spacer is being used. The cell was flushed with H_2 gas then 150 psi of H_2 was introduced. A cycle of 18 amp charge for 35 minutes was set up. The cell has run 1228 cycles to date, and is still running. Figure 4 shows the performance. The voltage has slowly risen to 0.325 volts and may stabilize.

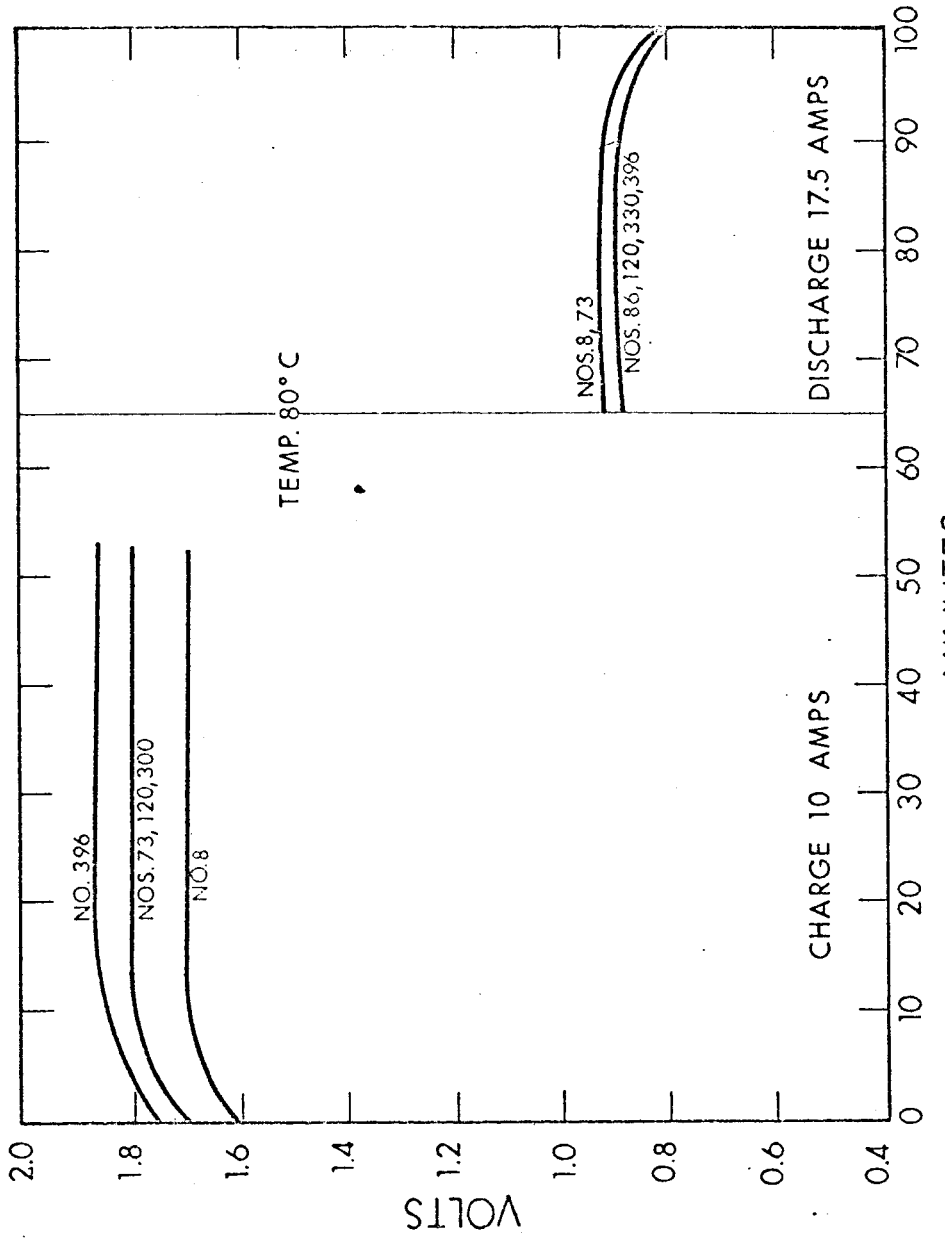

Figure 2. Cycling Performance of Cell 259

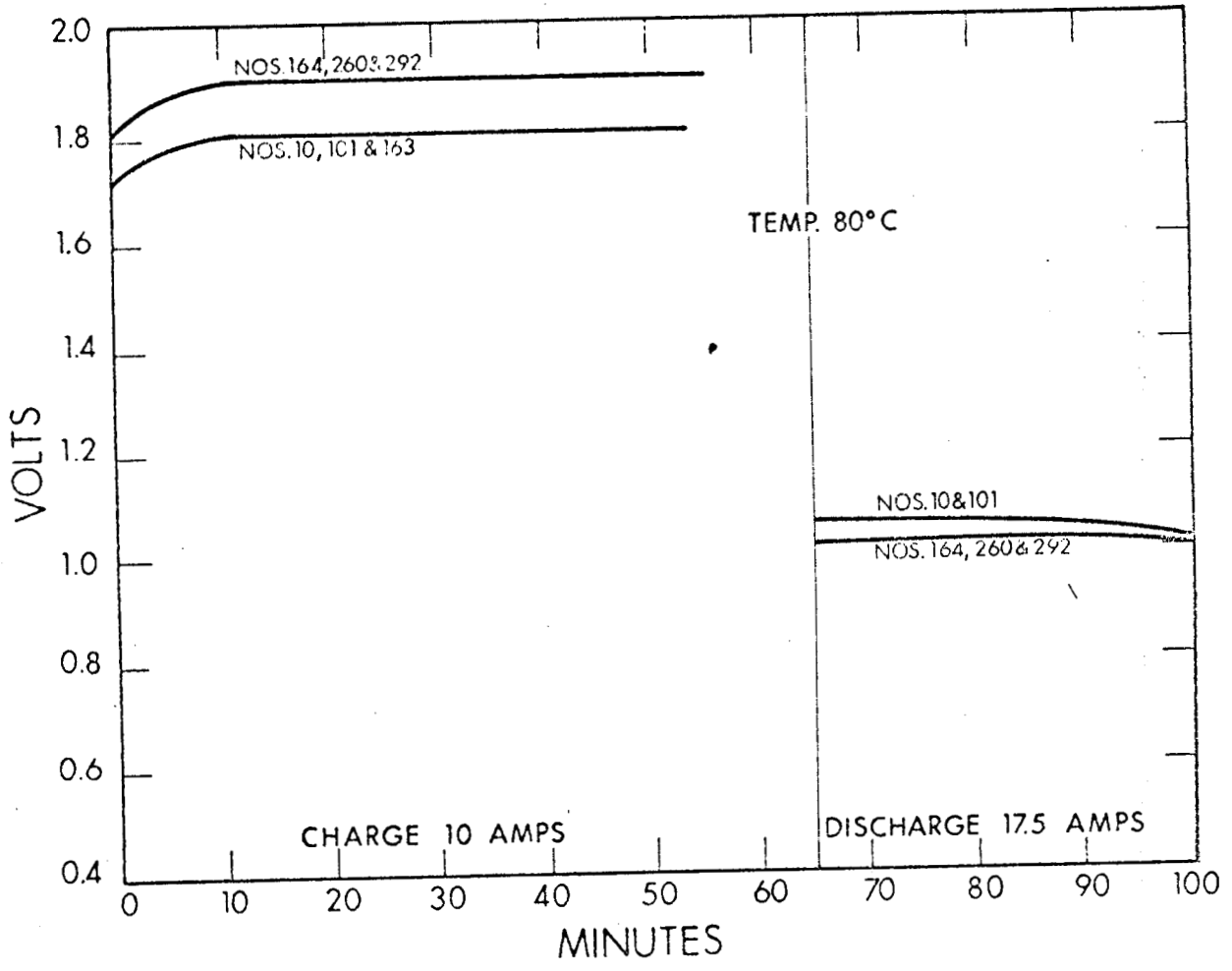

Figure 3. Performance of Cell 274

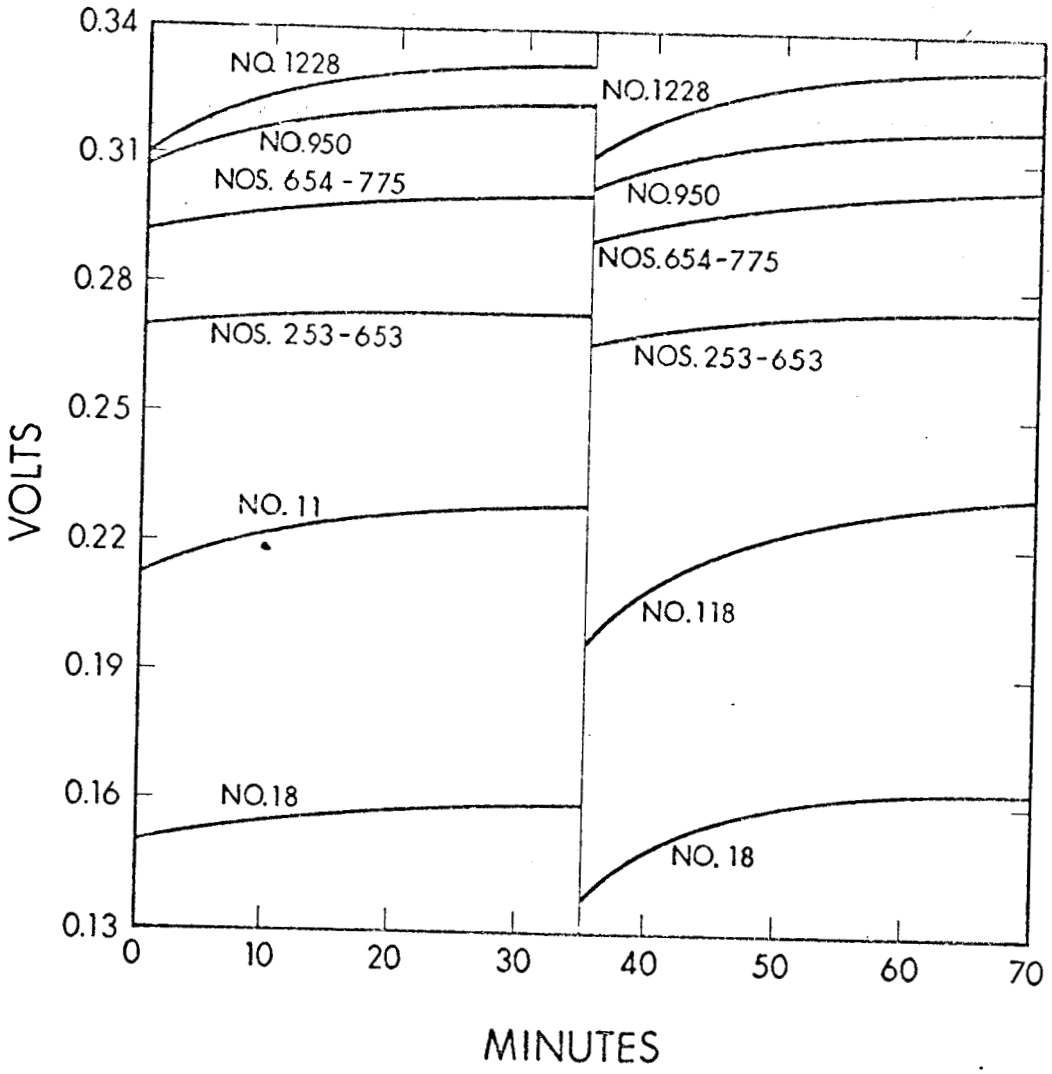

Figure 4. Cycling Performance of H_2 Concentration Cell 265

2.1.3 REFERENCE CELLS

In order to characterize the American Cyanamid and EOS electrodes used in the EOS fuel cell, reference cell testing is being continued. Cell 271 contained an AB6 American Cyanamid oxygen electrode and a standard EOS electrode (of 20 mg Pt/cm^2). The matrix was made of a pasted KT-teflon membrane sandwiched between two 90 percent KT and 10 percent asbestos mats. On each side of the membrane was placed a mercuric oxide (HgO) reference electrode. The reference electrodes consisted of nickel screens on which HgO powder was pressed. Each screen had a nickel wire spot welded on one end; the wire was fed out through the 60-mil insulating spacer. Reference cell 271 ran two cycles then began to self discharge. The cause could not be determined by visual inspection.

Another reference cell, No. 272, was built in the same manner as above and failed in like manner.

Reference cell No. 273 was built in the same manner as above. This cell ran 30 cycles before it failed to hold a charge. Figures 5 and 6 show the charge and discharge polarization curves for this cell. These curves are typical when compared to previous reference cell data.

Another reference cell, No. 275, was built in the same manner as above. This cell performed for 43 cycles before it failed to retain a charge.

Since this type of matrix arrangement has successfully demonstrated long cycle life without cross gas leakage in regular cycling tests, the inclusion of the reference electrode must be causing the cross gas leakage. This may result from the depressions caused by the reference wires which are fed into the cell through the matrix. In the future, attempts will be made to use thinner wires.

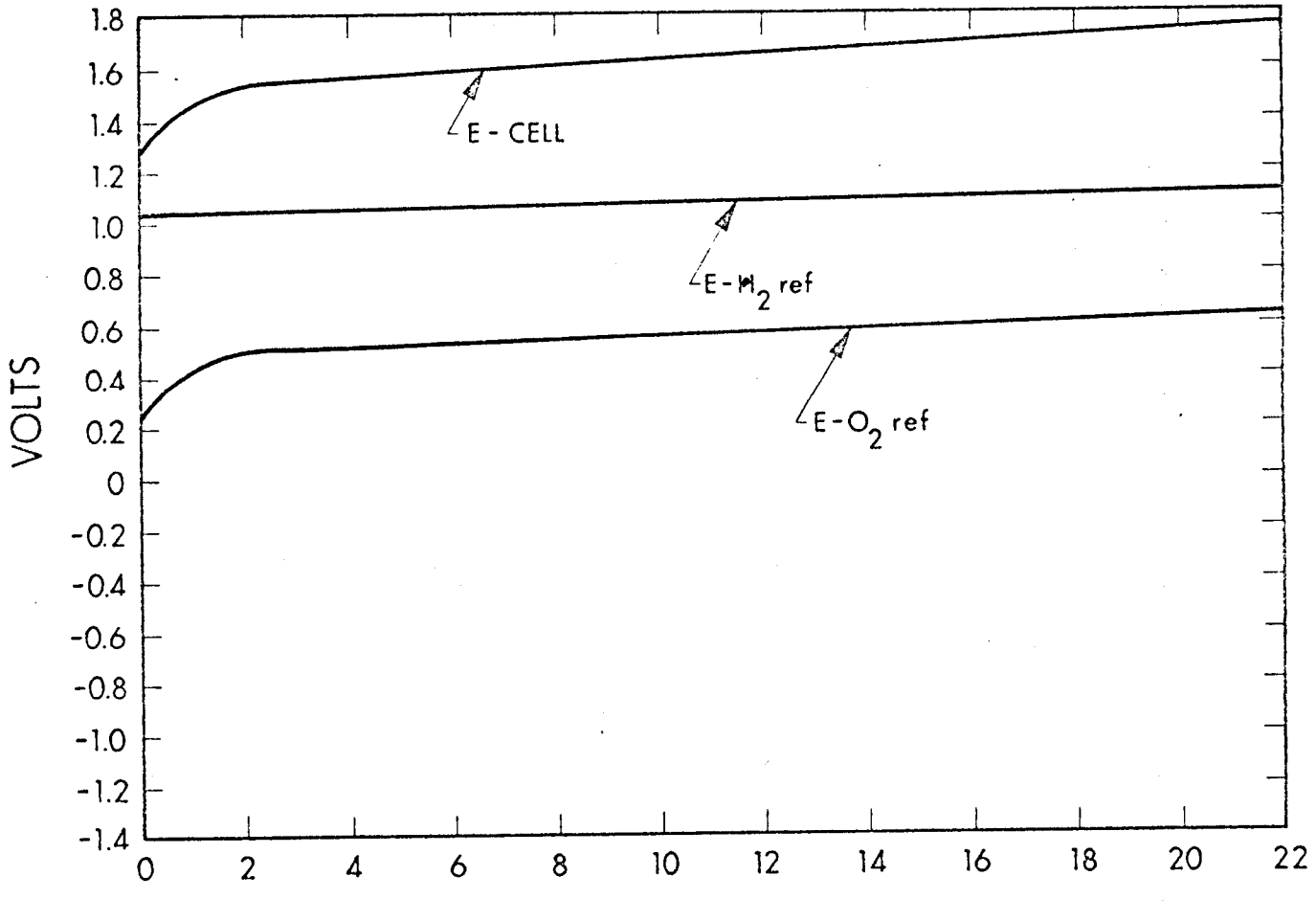

Figure 5. Charge Polarization of Reference Cell 273

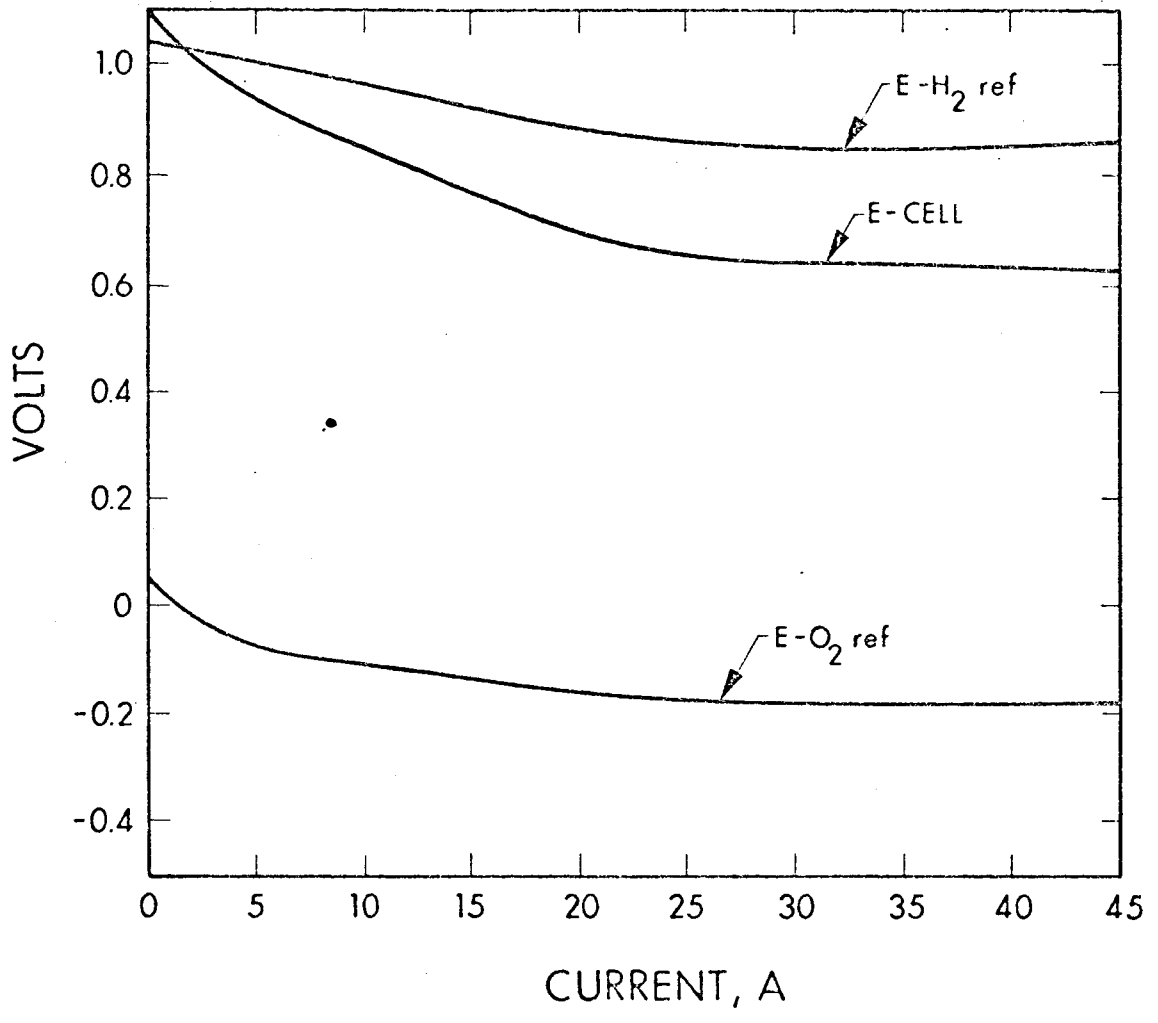

Figure 6. Discharge Polarization of Reference Cell 2.1

2.2 SIX CELL TESTING

A six cell unit, No. 100-13, was assembled during the last report period. The O_2 electrodes were American Cyanamid AB-6 type, and the H_2 electrodes were EOS 25 mg Pt/cm^2 carbonyl nickel plaques. The matrixes consisted of 50 percent KT-50 percent teflon pasted membrane sandwiched between two 90 percent KT-10 percent asbestos mats. Forty gm of 40 percent KOH was added to the matrixes and 60-mil spacers were used.

As can be seen in Fig. 7, the cell ran well with no degradation for 235 cycles. Near the end of charge at cycle 236 the cell pressure rose from 350 psi to 450 psi in less than a second. The cell voltage rapidly fell to zero. When taken apart, it was evident the cell stack was damaged by an extremely fast recombination of the gases. Upon inspection the cause of failure was found in the H_2 end plate. As can be seen in Fig. 8, a photograph of the end plate, at the spot the arrow indicates the inside sealing edge of the plate is warped upward. The warpage is a swelling caused by the formation of magnesium oxide from exposed magnesium and KOH. The swelling forced the end plate and bipolar plate apart, eventually allowing the gases to rapidly mix and recombine. This plate had been previously used and reworked by patching holes in the nickel plate with silver epoxy, then plating gold over the patch.

Figure 8 shows that not one of the patches held and corrosion occurred at all the spots repaired. Another six-cell unit will be built and tested as soon as new hardware is obtained.

2.3 MATRIX FABRICATION AND SCREENING

Fabrication of composite matrixes using KT, asbestos and teflon pressed together was explored during this period. Table II summarizes the

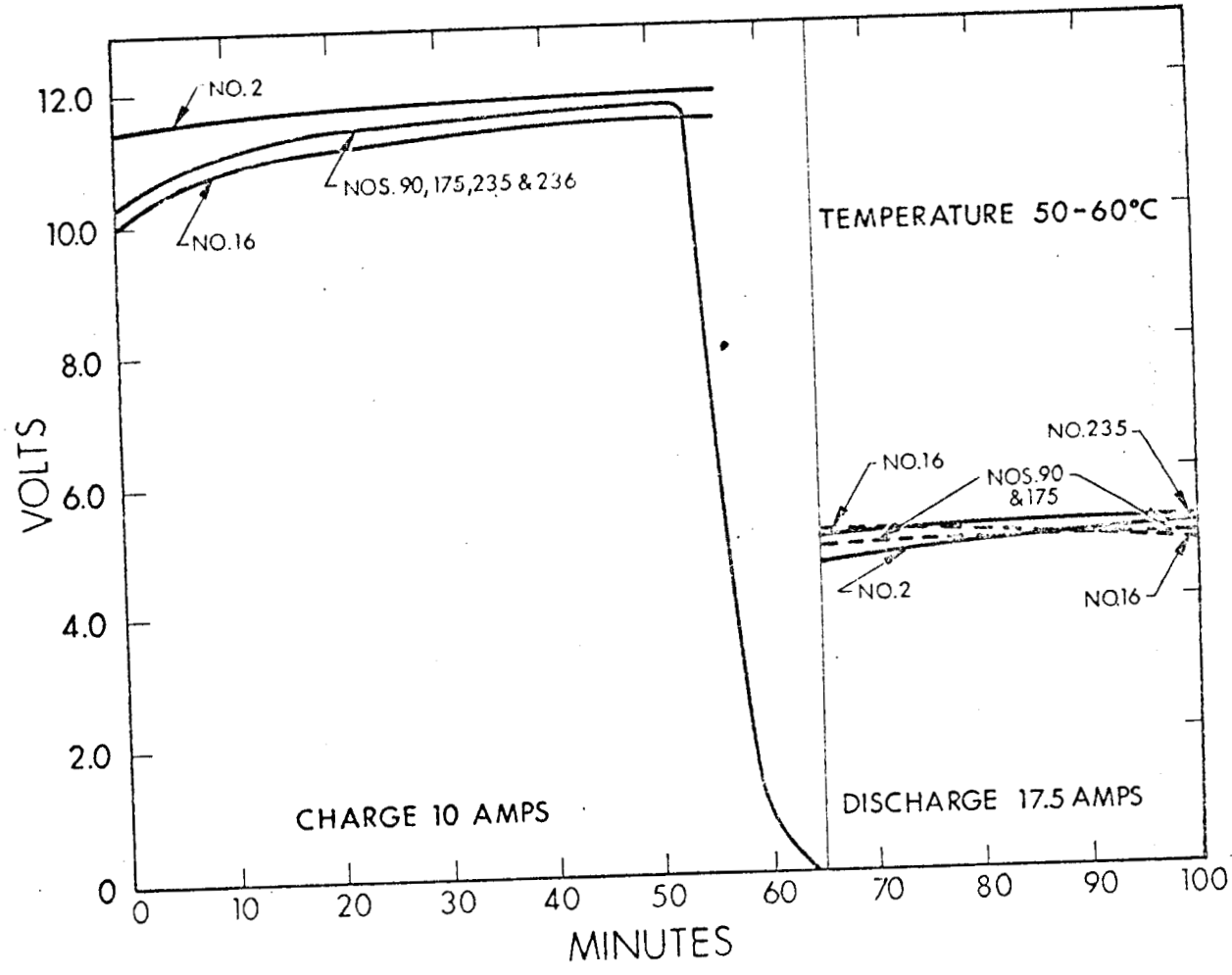

Figure 7. Performance of Six-Cell Unit No. 100-13

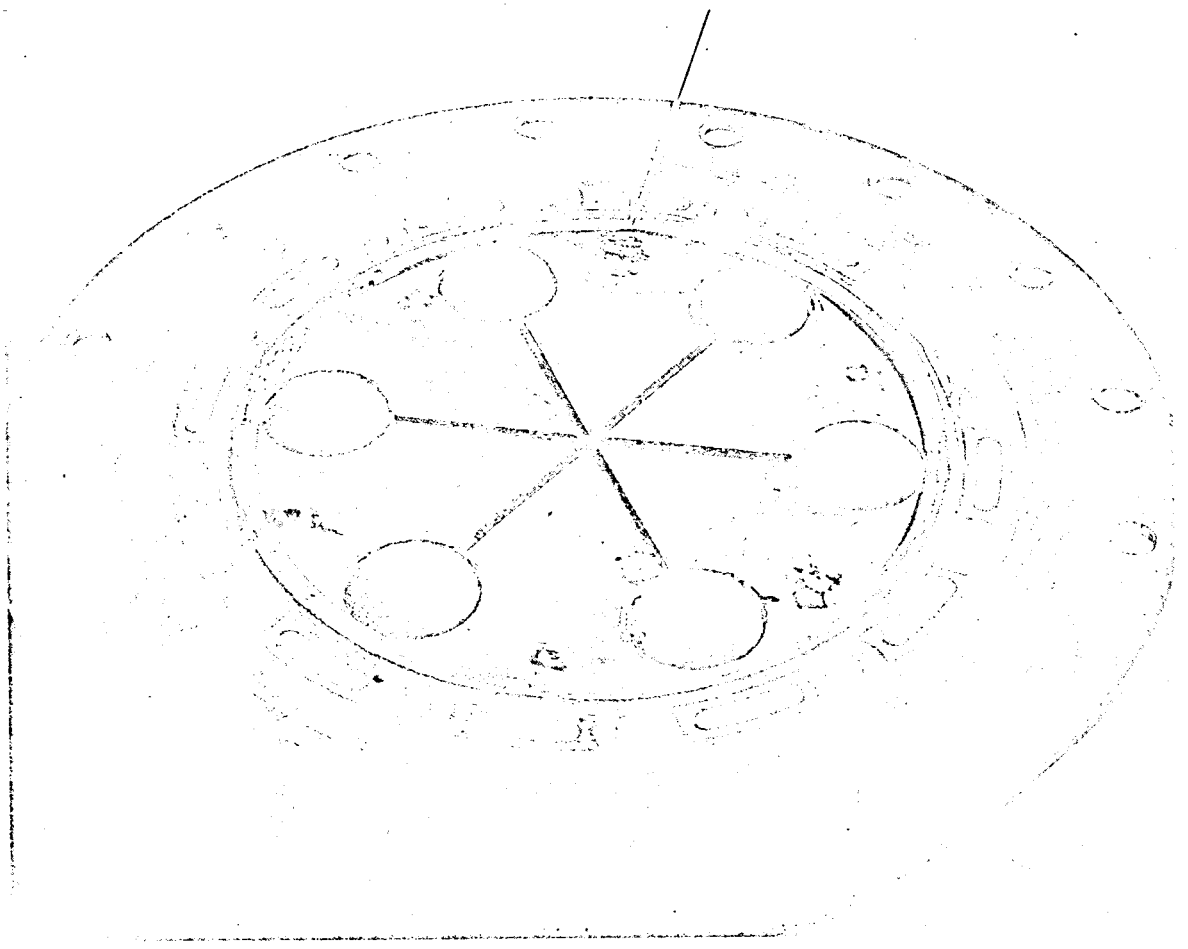

Figure 8. H_2 End Plate From Six-Cell Unit No. 100-13

TABLE II

Sample	Composition	Bubble-through psi	Resistivity Ω-cm	Resistance	Compression psi	Thickness (wet) mils	Thickness (dry) mils
M-1	Sandwich two 90/10 KT and asbestos mats, 50/50 KT and teflon 100 mesh screen membrane between mats pressed ½ hour at 124 psi	15	32.4 46.8 40.8 37.4	0.136 0.126 0.110 0.096	0 71 142 213	71 51 41 31	76
M-2	90/10 KT and asbestos mat pressed at ½ hour 124 psi	5	77 105 122 218	0.137 0.117 0.102 0.097	0 213 355 390	82 20 15 8	34
M-3	Matrix consisting of 82% KT, 10% asbestos and 8% teflon pressed at ½ hour 124 psi	20	37.0 27.7 24.6 23.7 21.2 25.2	0.167 0.117 0.097 0.087 0.072 0.067	0 160 284 390 710 850	81 76 71 66 61 48	67
M-4	Matrix consisting of 83.5% KT 8.25% asbestos 8.25% teflon not pressed	10	16.5 19.3 19.4 19.5 20.6 32.7	0.137 0.137 0.127 0.117 0.112 0.157	0 178 213 213 248 284	148 129 118 108 98 88	145

screening test results. Sample M-1 is the standard sandwiched matrix used in many of the current tests. Sample M-2 is a standard 90 percent KT/10 percent teflon matrix. The bubble-through pressure of 15 psi for the matrix (M-1) and 5 psi for the mat (M-2) along with the respective resistivity data give a baseline to compare the new structures with. Samples M-3 and M-4 are the KT, asbestos, teflon composites. The variable in fabrication is that sample M-4 was unpressed. The pressed matrix demonstrated the superior bubble through test of 20 psi. The unpressed matrix gave a result of 10 psi which is below that of the sandwiched matrix but better than the pressed KT/asbestos, mat (M-2). A pressed matrix similar to sample M-3 is currently being used in cell No. 274 with excellent results.

2.4 PLATINUM ANALYSIS OF O_2 CONCENTRATION CELLS

To determine whether platinum migration occurs by some soluble form into the matrix where it is reduced by hydrogen, the following test was performed on cells No. 252, 257 and 260. The cells were flushed with O_2 gas, then 150 psi of O_2 gas was introduced. A cycle of 18 amps forward charge for 35 minutes and 18 amps reverse charge for 35 minutes was set up. At the end of 57 cycles the cell was shut down and purged with H_2 gas. 150 psi of H_2 gas was added to the cell and it was left on stand for 24 hours. At the end of this period the cell was disassembled and the membrane analysed for platinum. The results are as follows:

Cell 252	0.115 mg Pt/cm^2
Cell 257	0.0088 mg Pt/cm^2
Cell 260	0.0036 mg Pt/cm^2

The results show a definite transfer of platinum. The reverse cycling in the O_2 concentration mode is extreme and may not represent what is

occurring in a functioning fuel cell. Additional platinum analysis will be done on the longer life cells in order to establish a quantitative basis to evaluate this problem.

SECTION 3

PLANS FOR THE NEXT PERIOD

Single-cell cycling tests and lab screening will be continued to evaluate KT matrixes of different total weight, electrolyte-to-matrix weight ratios, thicknesses, compression ratios, and additions of asbestos teflon, polypropylene, and other fibers that can improve the structure of the matrix. Another reference cell will be assembled and cycled. Fabrication of the 34 cell unit will continue.